Technical Completion Report

QUANTIFYING RECREATION IMPACTS ON A HEAVILY-USED SOUTHWESTERN STREAM

Eisenhower Consortium Grant 300
USDA RMF&RES 16-901-GR

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ABSTRACT

During the summer of 1979 Slide Rock, a 500 foot segment of Oak Creek (a perennial tributary of the Verde River, Arizona) was intensively studied to determine what, if any, impact heavy recreational use had on the aquatic ecosystem.

Data from chemical, bacteriological and microbiological examinations of the Slide Rock ecosystem is reported and discussed. Chemical examinations included analysis for NO_3, NH_4, TKN, PO_4, and TP while bacteriological examinations were made for fecal coliforms and fecal streptoccoci. Microbiological examinations resulted in a very thorough analysis of the periphyton communities at the sample site.

The data suggest that this stream ecosystem is very resilient to heavy recreation use (as many as 523 persons per acre) and that the biotic micro-components can assimilate intermittent inputs from recreation activity very rapidly with no significant modification in community structure.

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INTRODUCTION

Water-based recreational opportunities are notably lacking throughout Arizona, and there are only a few perennially-flowing streams within the state. Oak Creek, a tributary of the Verde River of Central Arizona, is one such stream however, and in its upper reaches it flows through, and indeed has created, the widely-acclaimed scenic area known as Oak Creek Canyon. Most of the lands surrounding the canyon as well as most of the canyon itself are principally in public ownership and are under the management direction of the Coconino National Forest. In 1976, the U.S. Forest Service estimated the total number of visitors to Oak Creek Canyon to be about 1,113,700 (Sedona Interagency Study, n.d.), a value which is equal to about one-half of Arizona's population.

The Slide Rock segment of Oak Creek Canyon is a location which receives a particularly heavy impact from this visitation because of its several unique properties. At this location the constant flow of Oak Creek has eroded a series of narrow chutes into the underlying stream bed of Supai sandstone and has also flushed most of the alluvium out of the channel itself. Individuals thus are able to "slide" through these chutes without noticeable difficulty, passing over the smooth rock surfaces and ending in a calm pool. Moreover, the chutes are easily accessible from the paved highway (U.S. 89A) which winds through Oak Creek Canyon. In 1978, as many as 800 persons per day were observed using the Slide Rock site for various activities: this figure is significant in that the total usable area at Slide Rock is only about 500 feet long and 100 feet wide.

Scope:

To date, most studies of recreational impacts on water quality have focused primarily on the potential increase in disease-causing organisms resulting from fecal contamination. For the purpose of such investigations relatively benign organisms (i.e., fecal coliforms and fecal streptococci) are considered as indicators of possible contamination. Their use and identification has been discussed by a number of authors (see Lin et al. 1974), yet it is important to note that the monitoring of bacterial contamination gives no indication of any subtle changes in the fresh-water ecosystems which might have resulted from the intensive sort of recreational activities which are found at Slide Rock. For instance, a slight increase in the loading of a specific nutrient could bring about changes in the entire biotic component of the stream system, or a minor shift in pH, or a similar single parameter, might result in increased (or decreased) biological activity.

In accordance with the general principle of multiple-use management, activities on National Forest lands need to be planned to accomodate the entire range of beneficial uses which are applicable for the area. Thus, other approaches for monitoring the total impacts of recreation use on water quality, besides just bacteriological monitoring, need to be implemented.

This study was undertaken to determine if the recreational activities at Slide Rock produced any detectable changes in the aquatic ecosystem. Because of the importance of producer organisms in any aquatic ecosystem, a major component of the research effort was to determine if there were any changes in the diatom assemblages during the recreational-use period

of 1979, and to learn if such changes might serve to integrate the total effect of full-body contact activities. A concurrent objective of the study was to monitor selected water quality parameters during the same period at three locations, above and below and within the Slide Rock segment, and to attempt to correlate any observed changes with recreational activity.

Background:

Fundamentally, the hydrologic cycle depicts water movement throughout any ecosystem. Moreover, the origin of the constituents found in water can have any or all of four major sources: the atmosphere, the biological community (including man), the soil, and the weathering of parent materials. Thus as water flows through an ecosystem it comes in contact with these constituent sources, and both chemical reactions and physical processes occur at that point. These reactions and processes, then, determine the ultimate composition of natural waters.

Streams flowing from watersheds in a relatively natural state contain quantities of nutrients and particulates which characterize the baseline water quality of that flow. If these characteristics are known, the effects of a perturbation to the watershed and the resultant change in water quality can be detected.

This approach to water quality has been used by several forest ecologists to determine the effects of management and land uses on the ecosystem. In practice watersheds, in an undisturbed state, are gauged and specific parameters are monitored to establish baseline values. A specific treatment is then initiated and any changes in the several

physical and chemical parameters, from those noted in the undisturbed state, are then statistically attributable to the treatment.

Research on such experimental watersheds has recently provided a wealth of data on nutrient cycling, beginning with the Hubbard Brook Study (Borman and Likens 1967), and has documented the nutrient losses in response to forest perturbations such as timber harvesting, fertilization, and herbicide treatments (Fredriksen et al. 1975). Information obtained from these types of studies has given land managers valuable knowledge with which to make managerial decisions, and they are now able to utilize the silvicultural methods which will impact the water quality the least as well as which will maintain onsite productivity by keeping nutrient loss to a minimum.

Bacteriological Water Quality:

Fecal coliform and fecal streptococci have long been accepted as indicators of pollution. These bacteria are contained within the intestines of all warm-blooded animals, including man, and consequently they are wide spread. They are commonly used to indicate the presence of disease-causing organisms because the techniques required to isolate the pathogenic bacteria and viruses from water are very time consuming and the cost of equipment required is prohibitive (Lin et al. 1974).

Geldreich (cited in Lin et al. 1974) stated that the ratio of fecal coliforms to fecal streptococci (FC:FS) is greater than four in humans and less than 0.7 in other warm-blooded mammals. Therefore, he indicated, the computation of this ratio should indicate the source of fecal contamination. However, McFeters and Stuart (1972) noted that

coliform indicators may or may not survive long enough to be identified, depending on the physical and chemical make-up of the water. Kunkle and Meiman (1967) found that, in a stream draining a heavily-grazed watershed, fecal coliform bacteria were 16 times greater in concentration than in water from a more lightly-grazed area. Also, the latter stream was less populated with fecal streptococci bacteria than might be expected since it showed less than twice the concentration of these organisms than did the heavily-grazed area. They used caution when comparing their results with that of other researchers, stating that environmental conditions in the cold pure mountain streams of their study area are drastically different than those found in warmer, "contaminated," low elevation streams. In 1968, Kunkle and Meiman computed the FC/FS ratio from a site where the contamination was undoubtably the result of grazing impact: the ratio averaged 4.4. Thus it appears that the FC/FS ratio does not, necessarily, indicate the source of fecal contamination.

Morrison and Fair (1966) found that overland flow was the single most important factor involved in the variation of the bacterial and chemical variables studied. By continuous sampling during periods of increasing streamflow resulting from precipitation, it was determined that the bacterial and chemical variables showed an immediate increase at the beginning of overland flow, followed by a decrease near the crest of the hydrograph. Kunkle and Meiman (1968) concurred with their findings on bacteria.

Diurnal variations of bacterial counts have also been found (Kunkle and Meiman 1968). Evening maximums in concentration followed afternoon minimums, while morning bacterial counts usually fell between the two.

The cycle was apparently related to the rising stream stages of early evening when streambank flushing took place.

Recreation and Water Quality:

Recreation is a land use activity which is specifically designated as a benefit to be derived from National Forest lands. Present day society is demanding increasing opportunities for outdoor recreation and water is one focal point (Aukerman and Springer 1976). The National Water Commission (1973) stated that one-half of all outdoor recreation activity is in some way associated with water.

The utilization of water bodies for recreation has serious implications if one considers that the same water must be used as a domestic water supply. William Bullard (cited in Aukerman and Springer 1976) in a speech to the Forest Management Symposium in Corvallis, Oregon noted:

> "A problem that is developing everywhere, and which in places is becoming intolerable, is that of pollution arising from recreational use. Most recreation in wildlands is associated with water, and most recreation areas are located along streams and lakes. Sewage and garbage disposal present problems almost of urban proportions, and disposal occurs high in the watershed near stream sources and above other uses."

There is a paucity of knowledge about the total impact of recreation on water quality. The parameters measured, in most of the studies that have been reported to date, appear to have been mainly of a bacterial nature.

Stuart et al. (1971) studied the bacterial water quality of two watersheds, one which was open to recreational activities and one which was closed to all human activity. They observed higher bacterial counts in the water from the closed watershed than from the one which was open

to recreation use. The higher counts were attributed to the closed area being a refuge for large game animals, since the area was free from disturbances. However, upon opening the watershed to recreational use, the bacterial counts were found to decrease. The human activities apparently dispersed the large wildlife population which had been contributing to the previous bacterial population.

Skinner et al. (1976) studied and compared the bacterial water quality of three watersheds that were each utilized differently (one for grazing, one for recreation and one was designated a non-use area) during three consecutive summers. They reported that the bacterial counts showed a seasonal variation and reached a maximum concentration in late summer. They provide no explanation for this trend. However, they did compare the natural area with the other two areas and the results indicated that the natural area was the least polluted. These values contradict those of Stuart et al. (1971).

The effects of camper concentrations and different types of campers on water quality was studied by Aukerman et al. (1976). The findings of this study indicate that recreational use, at its present rate, was not a significant cause of bacterial water pollution. They found no association between increasing levels of camper concentrations in campgrounds. In fact, they found a trend toward more and higher bacterial density increases during low camper use periods, which may have been attributable to rainfall. This supports the work of Kunkle and Meiman (1968) and Morrison and Fair (1966). Their results also showed that campgrounds utilized by motorized vehicles contributed significantly more bacteria than those utilized by backpack campers.

In contrast, Varness et al. (1978) examined the effects of intensive motorized camping without sanitary facilities on bacterial water quality. They found that the bacterial densities were consistently higher during weekends than during weekday periods. This correlated directly with the increased recreational use of the watershed. Furthermore, diurnal sampling at sites above the campgrounds showed highest densities in the early morning and early evenings, and lowest in the afternoons. These findings support those of Kunkle and Meiman (1968). In contrast, diurnal sampling of sites below camping areas showed indicator densities to be low in morning hours, increasing dramatically in the afternoons, and decreasing in the evenings. This increase correlated directly with the highest human activity on the site.

In the study of the chemical and microbiological characteristics of two mountain lakes in Northern Arizona, Oakly et al. (1977) found that shore contamination was the major factor of pollution, while the center water remained relatively free of pollution. Both lakes studied were nutrient poor and hence, highly oligotrophic. No noticeable increases in chemical content were found.

Sommerfeld et al. (1979) found in their study of both the physico-chemical and the bacteriological water quality of the East Verde River, Arizona, that more than twenty percent of the samples exceeded the bacteriological water quality standards for water designated for full-body contact. Furthermore, increases in fecal coliforms densities were associated with the days of heaviest recreational activities. These findings support those of Varness et al. (1978) and contradict those of Aukerman et al. (1976). They also found that nitrate and phosphate

concentrations did not increase over the weekend and holiday periods as did fecal coliforms.

Studies in Oak Creek:

There have been several studies on the water quality of Oak Creek. The Northern Arizona Council of Governments (NACOG 1978) reviewed the water quality of Oak Creek above Sedona. They state that the water quality in this segment was generally excellent with the exception of certain bacterial problems which were sporadic in occurrence. They also noted that phosphate levels occasionally exceed the proposed standard of 0.20 mg/1. and that there is some correlation between fecal wastes, as measured by coliforms, and phosphate levels.

Rumery (n.d.) reported that the FC/FS ratios of bacteria collected at Slide Rock indicate animals to be the primary source of contamination. Barnett (1977) came to somewhat the same conclusion when he stated that dogs were contributing to the degradation of water quality at Slide Rock.

In an internal report to the Forest Service, Barnett (1977) reported that, during the summer of 1977, fecal coliform counts exceeded the 200 colonies per 100 ml. standard (as stated in the Water Quality Standards for Surface Waters in Arizona) eleven times out of a total of twenty-eight samples. When he plotted fecal coliform counts against the total number of people using the area at one time, the graph showed that when between 250 and 350 people were utilizing Slide Rock the bacteria count would exceed the state standards. The Forest Service also sampled the bacteria at Slide Rock in 1978. Barnett (1978) found that thirteen samples exceeded the state standard. Because the State of Arizona has set standards

indicating at which point the water becomes unfit for water-body contact activities, recreational use of the area apparently has degraded the water enough to curtail human activity.

Bacterial counts indicate practically nothing about changes in the aquatic ecosystem. Yet if bacteria are being added to the stream by fecal wastes, then possibly other materials besides bacteria could likewise be added by human activities, with a resulting change in the chemical or nutrient quality of the water.

Likens (1972) defines eutrophication as nutrient or organic matter enrichment, or both, that results in high biological productivity. Recent application of the term usually refers to those enrichments that are man caused. Possibly, monitoring water quality in terms of chemical nutrients could be another way of measuring human impact on the aquatic ecosystems. Moreover, nitrogen and phosphorous have long been recognized as the major factors in limiting the productivity of aquatic systems (Deevey 1972, Wetzel 1975, Hynes 1970) and because periphyton communities respond relatively quickly to changes in the aquatic ecosystem (they are producer organisms) they have the potential of being an integrative type of indicator organism. However they have, to date, been used only to a limited extent for this purpose and their potential is largely unrecognized. Diatoms have a number of unique characteristics which recommend them for this use: 1) they are positioned on submerged substrates and thus continuously receive constituents in the water, 2) populations within the community reproduce rapidly both intrinsically and in response to changes in the physico-chemical constituents of the water, 3) selected species have been identified to characterize specific chemical and

physical conditions in water systems and 4) they serve as a prime food source in the communities for higher trophic levels, and thus, modification of these communities will be reflected throughout the food chain.

METHODS

Site Description:

This study took place at Slide Rock, a recreation area along Oak Creek. The site is located about 21 miles south of Flagstaff, Arizona, along U.S. Highway 89A and is six miles north of Sedona, Arizona in T18N, R4W. Slide Rock is located immediately north of Oak Creek Bridge at an elevation of from 4,920 to 5,000 feet above mean sea level.

Oak Creek Canyon is a steep walled canyon dissecting the southern margin of the Colorado Plateau. Its chasm begins approximately 13 miles south of Flagstaff and extends southward 12 miles where it merges into the eastern margin of the broad Verde River Valley. Oak Creek is a permanent stream which is fed by springs from a fault zone and from elsewhere along non-faulted rocks at the base of the canyon walls (Museum of Northern Arizona 1962). Oak Creek has had since 1941, a cumulative mean discharge of 82.6 cubic feet per second measured near its terminus close to Cornville, Arizona at a site approximately twenty miles downstream of Slide Rock. The long-term mean monthly discharge near Cornville for May, June, July, August, and September are 34.3, 21.0, 24.4, and 38.0 cubic feet per second. However, measured discharges for Oak Creek above Slide Rock in 1979 were 12.0, 13.1, 11.5, and 10.9 on July 1, August 1, August 17, and August 27, respectively (P. Jackson, personal communication).

Data Collection:

In this study we attempted to measure the impact of water-related recreation activities at Slide Rock on the water quality of Oak Creek using three sampling sites. The first was immediately downstream of the last rock slide area and just upstream of a waterfall (and above the highway bridge over Oak Creek). The second site was about 500 feet upstream of the first one, and it was also above the main slide area. The third site was located about 600 feet above the second, and it was well above the area where most activities were noticed; essentially, it was outside the Slide Rock segment.

This sampling design was of a pretreatment/post-treatment type. Between sites two and three virtually no activity took place and this section was regarded as the pretreatment area, or the control: data from these two sampling points reflected water quality flowing into the area of heavy use. Since essentially all the users were concentrated between sites one and two, this section was regarded as the treatment section. Samples were taken at site one to measure the water quality of the stream as it was leaving the area of heavy use.

Field Procedures:

For chemical analysis, four samples were collected at each of the three sampling sites. Facing upstream, samples one through four were collected from left to right across the stream. The sampling period extended from May 13, 1979 through September 15, 1979. This interval included the summer period when Slide Rock received the most intense use, as well as a period before and after heavy use.

Samples were collected two times each week. One time was on a weekend when recreation use was high; the other time was a weekday when use was considerably less. In addition to the twice weekly sampling, the Fourth of July and the Labor Day weekends were sampled three and two times respectively. A total of 37 days were sampled. Samples were collected in 125 ml. polyethelene bottles in the early afternoon (1300-1500 hours) on each sampling date. All were treated with 0.5 ppm phenyl mercuric acetate (PMA) in the field. This application is sufficient to kill all organisms in the samples that might change the form of the chemical parameters which were measured (McSwain and Beal 1975). The samples were then transported, on ice, to the laboratory where they were stored at approximately two degrees Celsius, until they were analyzed.

On the same dates as samples for chemical analysis were being taken, as well as at some other times, the numbers of people using the Slide Rock area were tabulated as were the number of dogs observed in the area, the air temperature, the water temperature and the depth of the stream. (Some of these data as well as all the bacteriological samples were collected by U.S.F.S. personnel.)

A sampling program was initiated to record changes in the periphyton communities at Slide Rock throughout the summer. Three collecting points were established corresponding to the water chemistry sampling points, with one station located upstream of the principal recreational activity site and the other two stations located immediately adjacent to the heavily-used segment.

The intact unfractured nature of the stream bed precluded any sampling techniques where natural substrates could be removed from the

water. Intense recreational activities also made artificial sampling devices which floated unfeasible for colonization studies. Therefore a sampling device (described in Eisenhower Consortium Journal Series Publication No. 51) was designed to remove attached algae from the submerged substrate. Galvanized metal pipe with an inside diameter of 2.05 cm. was cut into lengths of 12 cm. and a sharpened beveled edge was then machined onto the end of the pipe with a metal lathe (Figure 1). A 0.6 cm. diameter hole was bored through the opposite end of the pipe in order to install a 16 cm. length bolt that provided the leverage necessary to twist the sharpened pipe into the sandstone substrate. By placing the pipe directly onto the substrate and applying a twisting motion, a circular groove approximately 0.5 cm. deep was cut into the substrate delineating an area of 3.3 cm^2. These 3.3 cm^2 circular grooves were defined as "colonization pads." Approximately 10 colonization pads were placed at each station and located in areas of similar current, light and water depth. Each colonization pad was thoroughly cleaned off with a stiff nylon brush to remove all the periphyton.

After a recolonization period of 21 days, four colonization pads were selected at random for quantitative sampling. A sharpened pipe (ID = 2.06 cm.) was refitted onto a colonization pad so that the pad and overlying column of water was totally isolated from the stream with 3-4 cm. of pipe above the air/water interface. The periphyton mat was then dislodged from the substrate by scrubbing the surface of the pad with a stiff circular nylon brush. This sample was evacuated from the pipe using a peristaltic "utility pump" (Manostat Co.) fitted with one meter of 0.635 cm. I.D. plastic tubing (Figure 1). The pump was powered by a

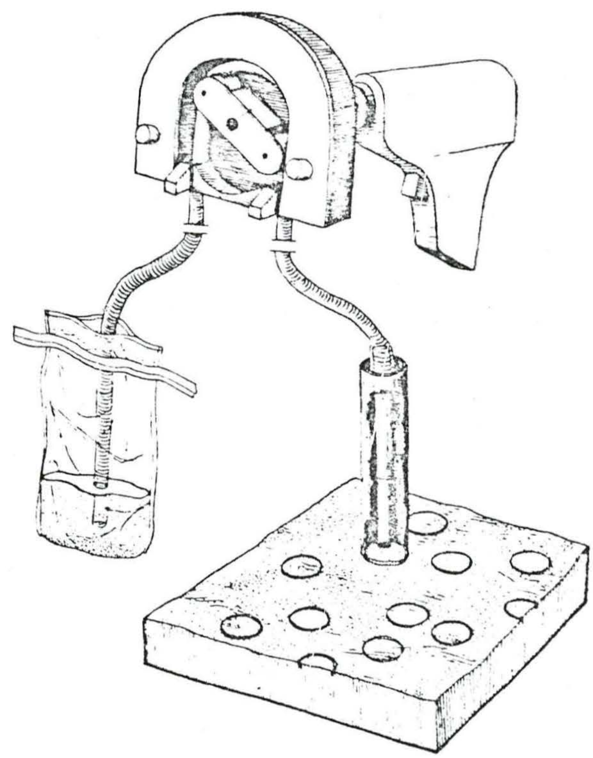

Figure 1

Portable Sample for Collecting Stream Periphyton

cordless electric drill. All samples were pumped into plastic bags and the tubing lines were then flushed to remove any periphyton remaining in the tubing.

Quantitative samples of periphyton standing crop were also obtained by twisting a sharpened pipe into the substrate adjacent to the colonization pads to a depth into the substrate where no loss of water out of the pipe was observed while carrying out the above procedure.

A total of 168 periphyton samples were collected on seven separate sampling dates at about three week intervals. Moreover four colonization and four standing crop samples were taken at each of the three stations at the same times. Current velocity, stream temperature and pH were also measured at each station.

Analytical Procedures:

a) Chemical Analysis:

Nitrate-nitrogen (NO_3-N), ammonia-nitrogen (NH_3-N), and orthophosphate-phosphorus (PO_4-P) were analyzed directly on the Technicon Autoanalyzer II System (Technicon 1974) using industrial methods 100-70W released September, 1973, 98-70W/B revised May, 1977, and 94-70W/B revised January, 1976.

Total Kjeldahl nitrogen and total phosphorous, however, required the use of a digestion procedure. This procedure, industrial method 376-75W/B revised November, 1978 (Technicon 1974) converts the nitrogen and phosphorous components of biological origin to ammonia and orthophosphate. The digested samples were prepared with the Technicon BD-40 Block Digester (Technicon 1974). Digested samples were then run through

the Technicon Autoanalyzer utilizing industrial method 329-74W/B revised November, 1978 (Technicon 1974).

When analyzing for total Kjeldahl nitrogen and total phosphorous, the four samples from each site were combined into one sample before digestion. Thus, only three samples for each date were analyzed for these parameters. One-way analysis of variance (Ryan et al. 1976) was used to test the differences in the concentrations of each chemical parameter (NO_3-N, NH_3-N, PO_4-P, TKN, Total Phosphorous) and the several independent variables: sample dates, sample sites, sample points, weekends versus weekdays, and raining versus not raining.

Two-way analysis of variance (Nie et al. 1975) was used to test for interactions among the variables listed in the one-way analysis of variance.

Regression analysis (Nie et al. 1975) was used to test the relationship of date, site, sample point, number of people, number of dogs, air temperature, water temperature, and stage with the chemical concentrations.

b) Bacteriological Analysis:

The bacteriological samples were cultured and analyzed using standardized MF (Millipore) techniques. The data were provided through an informal arrangement with personnel of the Coconino National Forest.

c) Periphyton Analysis:

The material collected from the substrates constituted the periphyton available for analysis. Three of the four collected samples were selected for taxonomic enumeration of the diatom assemblage component of the total periphyton community; the fourth sample was used for non-diatom

analysis.

These three diatom samples were brought to a 20 ml. volume following the hydrogen peroxide-potassium dichromate procedure described by Van der Werff (1953). Appropriate dilutions were made to ease counting procedures for various samples depending on cell densities. Aliquots of "cleaned" diatom material were dried onto 18 mm. circle coverslips and permanent slide preparations were made using Hyrax mounting medium. Cell density estimates were made with a Zeiss phase contrast microscope using a 40x Neofluor objective. At least 275 values were counted for each sample.

Community structure at each sampling station was computed by means of a commonly-used similarity index (or SIMI) for each sampling date. The formula is as follows:

$$\text{SIMI} = \frac{\sum_{i=1}^{s} \text{Pij Pin}}{\sqrt{\sum_{i=1}^{s} \text{Pij}^2}\sqrt{\sum_{i=1}^{s} \text{Pin}^2}}$$

Where Pij and Pin are the average relative abundances, expressed as a proportion for the collected dates, of the i-th species in the j-th community, and s is equal to the number of species. These relative values range from 0 to 1 with 1 suggesting identical community structure. See Sullivan (1977) or Tuchman and Blinn (1979) for examples. It should be noted that no statistically significant differences can be calculated by means of this particular SIMI.

RESULTS

Chemistry:

Nitrate Nitrogen

No significant difference was found between the individual sample points at each sample site, so the concentrations were reported as the means of the four values (see Table 1). A highly significant difference ($p = .01$) in nitrate concentrations occurred with respect to date, and the concentrations decreased throughout the sampling season. A highly significant difference between sample sites was also found; site one was lower in concentration than sites two and three. No significant differences were found when weekdays were compared against weekends and samples collected when it was raining versus days when it was not. Two-way analysis of variance indicated that none of the interaction terms were significant.

Regression analysis indicated that date was the most important variable in determining the nitrate concentration (see Figure 2); it had the highest correlation and was entered first in the forward selection process. All other variables added less than one percent to the R^2 value of the equation. Notably, the number of people present at the time of sampling had the lowest correlation with nitrate concentrations of all variables. (Regression summary tables and supporting data are found in Appendix 1.)

Table 1

Mean (n=4) Nitrate Concentrations (NO_3-N mg/l) of Oak Creek Water Samples Collected in 1979. Values in Parentheses are Standard Errors

Sampling Date	Site 1	Site 2	Site 3
5/13	0.0229 (0.0002)	0.0244 (0.0006)	0.0271 (0.0005)
5/15	0.0274 (0.0038)	0.0254 (0.0016)	0.0263 (0.0004)
5/20	0.0441 (0.0079)	0.0564 (0.0017)	0.0560 (0.0020)
5/22	0.0395 (0.0002)	0.0499 (0.0016)	0.0500 (0.0011)
5/26	0.0512 (0.0019)	0.0538 (0.0029)	0.0596 (0.0002)
5/29	0.0143 (0.0105)	0.0559 (0.00062)	0.0536 (0.0004)
6/03	0.0742 (0.0002)	0.0792 (0.0007)	0.0775 (0.0004)
6/05	0.0670 (0.0004)	0.0738 (0.0008)	0.0760 (0.0006)
6/10	0.0691 (0.0208)	0.0809 (0.0035)	0.0814 (0.0049)
6/12	0.0625 (0.0145)	0.0963 (0.0017)	0.0585 (0.0239)
6/17	0.0445 (0.0186)	0.0630 (0.0210)	0.0632 (0.0199)
6/19	0.0514 (0.0173)	0.0690 (0.0029)	0.0677 (0.0044)
6/24	0.0402 (0.0220)	0.0672 (0.0069)	0.0722 (0.0004)
6/26	0.0617 (0.0004)	0.0703 (0.0006)	0.0680 (0.0006)
6/30	0.0381 (0.0029)	0.0507 (0.0005)	0.0489 (0.0005)
7/02	0.0478 (0.0030)	0.0511 (0.0041)	0.0525 (0.0009)
7/04	0.0429 (0.0064)	0.0473 (0.0006)	0.0378 (0.0045)
7/07	0.0420 (0.0009)	0.0441 (0.0024)	0.0443 (0.0025)
7/10	0.0382 (0.0008)	0.0529 (0.0062)	0.0599 (0.0006)
7/14	0.0372 (0.0033)	0.0471 (0.0005)	0.0431 (0.0035)
7/17	0.0056 (0.0044)	0.0172 (0.0050)	0.0358 (0.0004)

Table 1 (continued)

Sampling Date	Site 1	Site 2	Site 3
7/22	0.0170 (0.0064)	0.0009 (0.0009)	0.0151 (0.0075)
7/25	0.0096 (0.0006)	0.0236 (0.0081)	0.0265 (0.0099)
7/29	0.0295 (0.0004)	0.0330 (0.0019)	0.0314 (0.0005)
7/31	0.0166 (0.0043)	0.0182 (0.0049)	0.0290 (0.0001)
8/05	0.0221 (0.0001)	0.0272 (0.0014)	0.0267 (0.0004)
8/07	0.0215 (0.0004)	0.0199 (0.0027)	0.0274 (0.0002)
8/14	0.0132 (0.0014)	0.0204 (0.0009)	0.0205 (0.0014)
8/19	0.0269 (0.0003)	0.0220 (0.0000)	0.0248 (0.0019)
8/21	0.0211 (0.0008)	0.0211 (0.0003)	0.0229 (0.0004)
8/26	0.0000 (0.0000)	0.0046 (0.0035)	0.0176 (0.0059)
8/29	0.0067 (0.0067)	0.0309 (0.0008)	0.0347 (0.0003)
9/01	0.0048 (0.0048)	0.0128 (0.0061)	0.0283 (0.0012)
9/03	0.0091 (0.0012)	0.0021 (0.0021)	0.0071 (0.0049)
9/09	0.0000	0.0000	0.0000
9/12	0.0000	0.0000	0.0000
9/15	0.0000	0.0000	0.0000

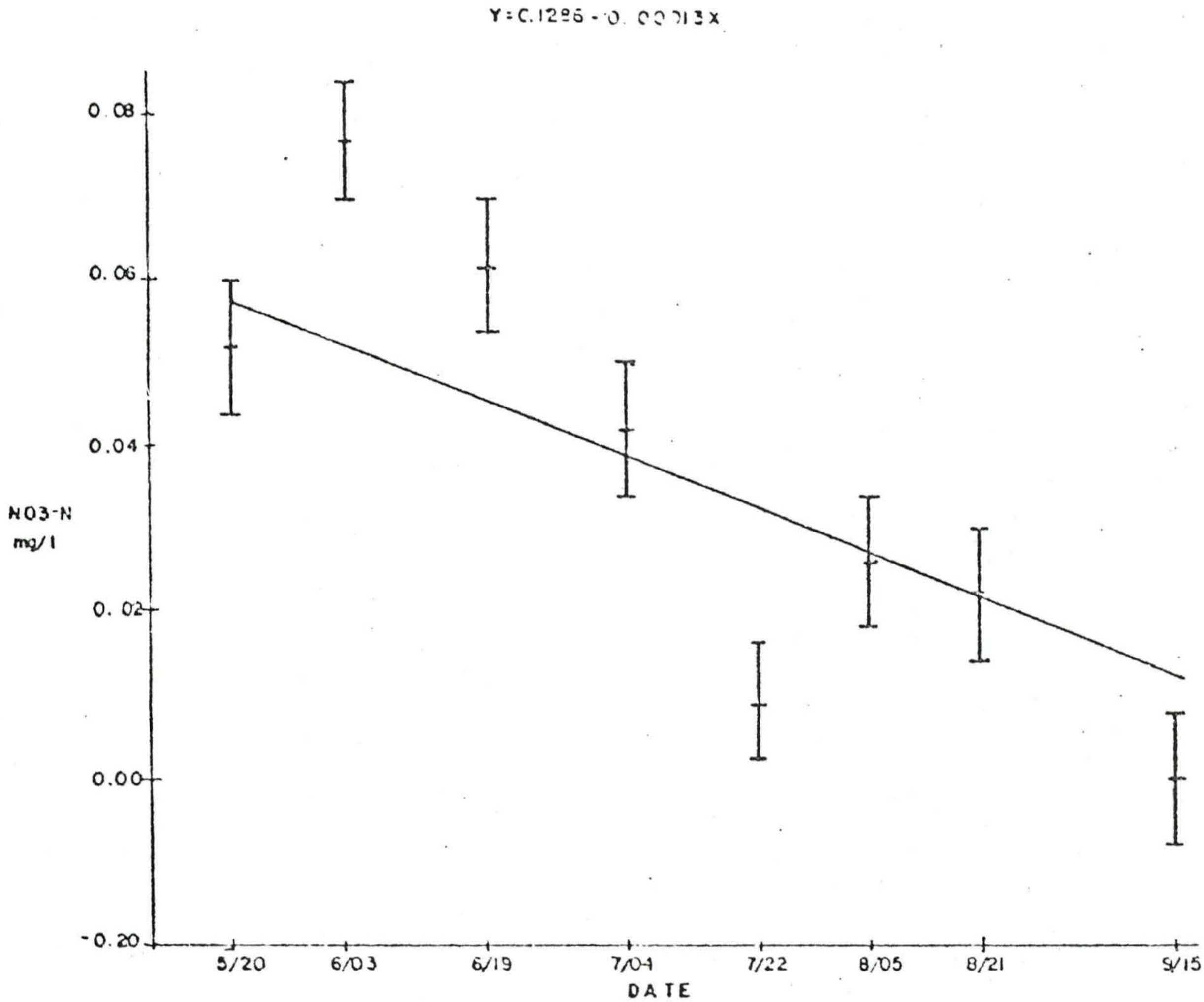

Figure 2

Regression (n=444) of Nitrate Concentrations (NO_3-N mg/l) Plotted Against Elapsed Time Since May 13, 1979, with Mean (n=12) Sample Concentrations for Eight Selected Dates

Ammonia Nitrogen

For the most part, ammonia was below the detectable limit of 0.02 mg/l. However, a significant difference ($p = .05$) in concentration occurred with respect to date (see Table 2). Most of the detectable values were in the beginning of the sampling season, declining to below the detectable limits through the rest of the sample period. No significant difference was found between sites, sample points, weekends as compared to weekdays, or when it was raining versus when it was not. No interactions were found to be significant.

Regression analysis was performed, and date had the highest correlation with the ammonia concentration. However, the R^2 values for all variables were below 10 percent.

Total Kjeldahl Nitrogen

Highly significant differences in total Kjeldahl nitrogen (TKN) concentrations occurred with respect to date: they steadily declined as the season progressed (see Table 3). No significant difference was found between sites. In addition, differences in concentration between weekends and weekdays, as well as when it was raining compared to when it was not, were found to be nonsignificant. No significant interactions were found.

Regression analysis revealed that date was the most important variable and it had the highest correlation of all the variables (see Figure 3). All others added less than one percent to the R^2 values. The number of people present during sampling had the lowest correlation of all the variables.

Table 2

Mean (n=4) Ammonia Concentrations (NH_3-N mg/l) of Oak Creek Water Samples Collected in 1979. Values in Parentheses are Standard Errors

Sampling Date	Site 1	Site 2	Site 3
5/13	0.0000	0.0173 (0.0106)	0.0158 (0.0101)
5/15	0.0262 (0.0162)	0.0066 (0.0066)	0.0341 (0.0194)
5/20	0.0131 (0.0079)	0.0000	0.0209 (0.0130)
5/22	0.0136 (0.0078)	0.0191 (0.0068)	0.0139 (0.0058)
5/26	0.0000	0.0351 (0.0269)	0.0000
5/29	0.0000	0.0000	0.0000
6/03	0.0000	0.0072 (0.0072)	0.0000
6/05	0.0000	0.0000	0.0000
6/10	0.0000	0.0000	0.0000
6/12	0.0000	0.0000	0.0000
6/17	0.0000	0.0179 (0.0179)	0.0065 (0.0065)
6/19	0.0000	0.0199 (0.0199)	0.0000
6/24	0.0110 (0.0110)	0.0000	0.0000
6/26	0.0000	0.0000	0.0000
6/30	0.0000	0.0000	0.0000
7/02	0.0074 (0.0074)	0.0105 (0.0105)	0.0296 (0.0120)
7/04	0.0000	0.0103 (0.0103)	0.0000
7/07	0.0109 (0.0109)	0.0000	0.0163 (0.0147)
7/10	0.0000	0.0000	0.0444 (0.0059)
7/14	0.0155 (0.0084)	0.0255 (0.0147)	0.0000
7/17	0.0000	0.0000	0.0000

Table 2 (continued)

Sampling Date	Site 1	Site 2	Site 3
7/22	0.0000	0.0000	0.0000
7/25	0.0000	0.0000	0.0000
7/29	0.0146 (0.0088)	0.0000	0.0072 (0.0072)
7/31	0.0000	0.0000	0.0000
8/05	0.0070 (0.0070)	0.0000	0.0000
8/07	0.0000	0.0000	0.0000
8/14	0.0000	0.0000	0.0000
8/19	0.0000	0.0000	0.0000
8/21	0.0000	0.0000	0.0000
8/26	0.0000	0.0000	0.0000
8/29	0.0000	0.0000	0.0000
9/01	0.0000	0.0000	0.0088 (0.0088)
9/03	0.0000	0.0000	0.0000
9/09	0.0000	0.0000	0.0000
9/12	0.0000	0.0000	0.0000
9/15	0.0000	010000	0.0000

Table 3

Total Kjeldahl Nitrogen Concentrations (TKN mg/l)
of Oak Creek Water Samples Collected in 1979

Sampling Date	Site 1	Site 2	Site 3
5/13	0.333	0.423	0.472
5/15	0.521	0.479	0.411
5/20	0.566	0.456	0.400
5/22	0.367	0.478	0.356
5/26	0.274	0.327	0.336
5/30	0.363	0.531	0.433
6/03	0.422	0.361	0.274
6/05	0.949	0.294	0.212
6/10	0.437	0.116	0.228
6/12	0.172	0.103	0.099
6/17	0.090	0.340	0.942
6/19	0.547	0.633	0.347
6/24	0.000	0.521	0.226
6/26	0.230	0.942	0.202
6/30	0.326	0.116	0.107
7/02	0.103	0.099	0.132
7/04	0.219	0.230	0.295
7/07	0.308	0.056	0.270
7/10	0.479	0.102	0.154
7/14	0.456	0.313	0.052
7/17	0.215	0.109	0.215
7/22	0.061	0.430	0.106

Table 3 (continued)

Sampling Date	Site 1	Site 2	Site 3
7/25	0.260	0.084	0.476
7/29	0.373	0.148	0.152
7/31	0.130	0.059	0.000
8/05	0.108	0.000	0.166
8/07	0.000	0.000	0.000
8/14	0.000	0.000	0.000
8/19	0.000	0.000	0.000
8/21	0.289	0.000	0.000
8/26	0.000	0.000	0.000
8/29	0.000	0.000	0.000
9/01	0.227	0.177	0.237
9/03	0.000	0.000	0.000
9/09	0.000	0.000	0.000
9/12	0.000	0.000	0.000
9/15	0.000	0.000	0.000

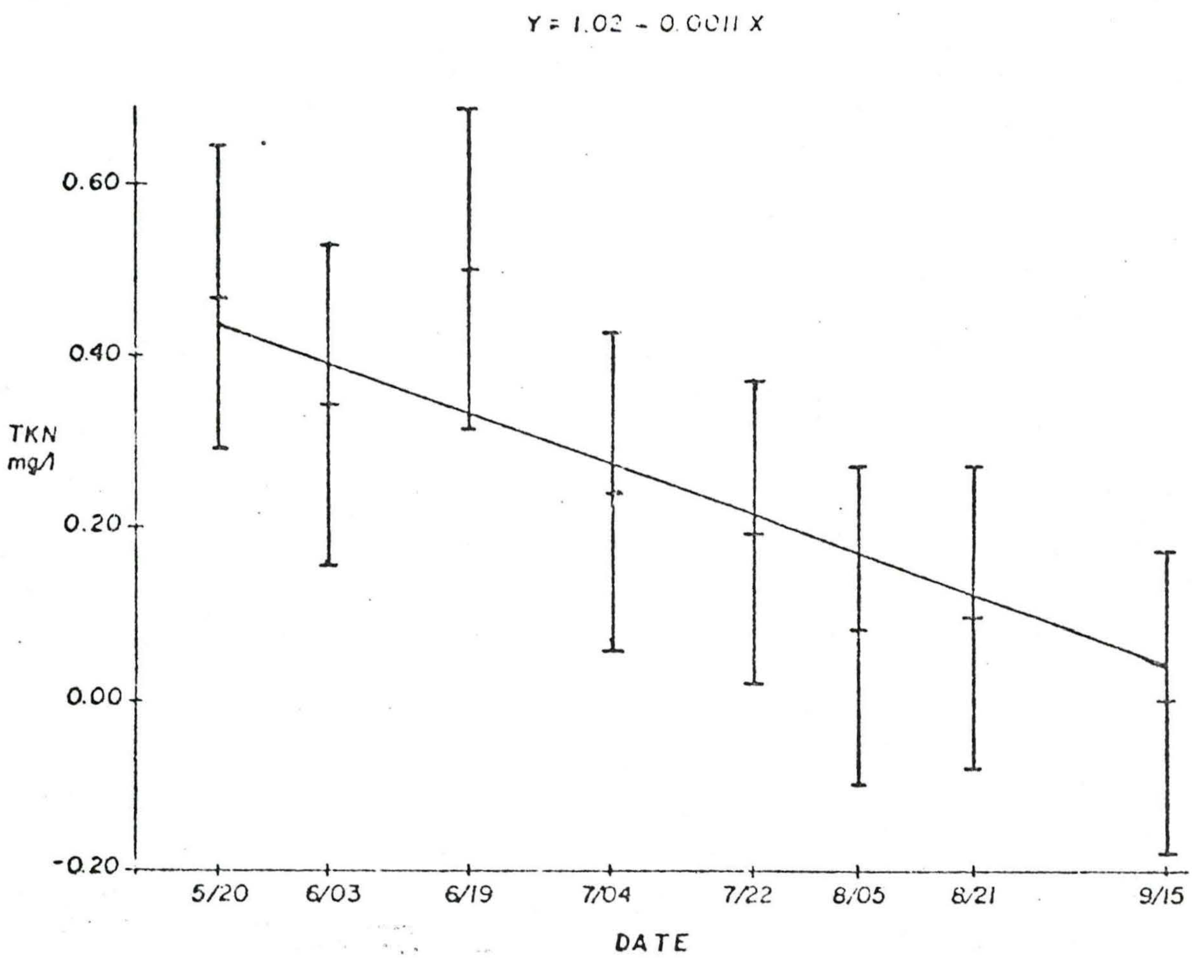

Figure 3

Regression (n=111) of Total Kjeldahl Nitrogen Concentrations (TKN mg/1) Plotted Against Elapsed Time Since May 13, 1979, with Mean (n=3) Sample Concentrations for Eight Selected Dates

Orthophosphate

No significant differences in orthophosphate concentrations were found between individual sample points across the stream at each sample site. The values were recorded as the means of the four samples at each site (see Table 4). (Again, a similar decreasing trend was evident throughout the season, nor was there a significant difference between sample sites, weekends or weekdays, or when it was raining compared to when it was not.) No interaction terms were found to be significant.

Regression analysis again indicated that date was the most important factor influencing the stream orthophosphate concentrations (see Figure 4). All other variables added less than one percent to the R^2 values.

Total Phosphorous

Highly significant differences in the concentration of total phosphorous also occurred with respect to date: as previously stated, the concentrations decreased as the season progressed (see Table 5). No significant difference was found between sample sites. A significant difference was not found between when it was raining and when it was not raining, nor was a difference noted for weekends as compared to weekdays. No interactions were found to be significant.

Regression analysis revealed a very low correlation of any of the variables with concentration. The R^2 values were below one percent for any combination of variables. However, date once again had the highest correlation with phosphorus concentrations (see Figure 5) and number of people had the lowest correlation.

Table 4

Mean (n=4) Orthophosphate Concentrations (PO_4-P mg/l) of Oak Creek Water Samples Collected in 1979. Values in Parentheses are Standard Errors

Sampling Data	Site 1	Site 2	Site 3
5/13	0.0338 (0.0003)	0.0329 (0.0022)	0.0363 (0.0039)
5/15	0.0353 (0.0028)	0.0292 (0.0032)	0.0320 (0.0054)
5/20	0.0285 (0.0015)	0.0324 (0.0005)	0.0359 (0.0059)
5/22	0.0321 (0.0018)	0.0346 (0.0018)	0.0311 (0.0009)
5/26	0.0328 (0.0005)	0.0300 (0.0018)	0.0349 (0.0009)
5/29	0.0340 (0.0014)	0.0324 (0.0016)	0.0302 (0.0021)
6/03	0.0269 (0.0022)	0.0373 (0.0015)	0.0275 (0.0005)
6/05	0.0329 (0.0003)	0.0270 (0.0023)	0.0270 (0.0005)
6/10	0.0367 (0.0043)	0.0245 (0.0007)	0.0288 (0.0016)
6/12	0.0301 (0.0007)	0.0314 (0.0018)	0.0255 (0.0041)
6/17	0.0277 (0.0020)	0.0316 (0.0013)	0.0228 (0.0013)
6/19	0.0293 (0.0032)	0.0288 (0.0009)	0.0302 (0.0009)
6/24	0.0188 (0.0036)	0.0185 (0.0024)	0.0226 (0.0019)
6/26	0.0146 (0.0084)	0.0032 (0.0032)	0.0179 (0.0020)
6/30	0.0081 (0.0046)	0.0160 (0.0021)	0.0165 (0.0004)
7/02	0.0280 (0.0005)	0.0169 (0.0013)	0.0246 (0.0026)
7/04	0.0238 (0.0009)	0.0169 (0.0013)	0.0171 (0.0005)
7/07	0.0244 (0.0008)	0.0194 (0.0002)	0.0241 (0.0015)
7/10	0.0169 (0.0009)	0.0209 (0.0044)	0.0214 (0.0011)
7/14	0.0289 (0.0021)	0.0221 (0.0015)	0.0224 (0.0011)
7/17	0.0232 (0.0003)	0.0188 (0.0013)	0.0199 (0.0005)

Table 4 (continued)

Sampling Data	Site 1	Site 2	Site 3
7/22	0.0198 (0.0011)	0.0169 (0.0002)	0.0168 (0.0009)
7/25	0.0176 (0.0018)	0.0119 (0.0044)	0.0092 (0.0092)
7/29	0.0231 (0.0015)	0.0168 (0.0016)	0.0175 (0.0006)
7/31	0.0000	0.0000	0.0077 (0.0027)
8/05	0.0197 (0.0018)	0.0119 (0.0004)	0.0188 (0.0019)
8/07	0.0055 (0.0032)	0.0030 (0.0029)	0.0114 (0.0038)
8/14	0.0157 (0.0035)	0.0122 (0.0041)	0.0000
8/19	0.0035 (0.0035)	0.0138 (0.0004)	0.0142 (0.0009)
8/21	0.0038 (0.0038)	0.0044 (0.0043)	0.0125 (0.0042)
8/26	0.0132 (0.0045)	0.0000	0.0024 (0.0024)
8/29	0.0062 (0.0036)	0.0000	0.0000
9/01	0.0000	0.0000	0.0136 (0.0047)
9/03	0.0129 (0.0048)	0.0000	0.0000
9/09	0.0000	0.0000	0.0000
9/12	0.0000	0.0000	0.0000
9/15	0.0000	0.0000	0.0000

Table 5

Total Phosphorous Concentrations (TP mg/l) of
Oak Creek Water Samples Collected in 1979

Sampling Date	Site 1	Site 2	Site 3
5/13	0.2597	0.2541	0.2960
5/15	0.0989	0.0682	0.0000
5/20	0.0438	0.0438	0.0438
5/22	0.0000	0.0240	0.0275
5/26	0.0213	0.0213	0.0000
5/30	0.0618	0.2236	0.0808
6/03	0.2672	0.2755	0.0641
6/05	0.4109	0.0487	0.0179
6/10	0.0256	0.0000	0.0679
6/12	0.0641	0.0538	0.2051
6/17	0.3426	0.0355	0.0228
6/19	0.0228	0.0228	0.0457
6/24	0.0381	0.0520	0.0000
6/26	0.0317	0.0000	0.0000
6/30	0.0318	0.0352	0.0000
7/02	0.0366	0.0316	0.0518
7/04	0.0556	0.0455	0.0316
7/07	0.0506	0.0316	0.0000
7/10	0.0241	0.0000	0.0000
7/14	0.0331	0.0000	0.0331
7/17	0.1013	0.0279	0.0000

Table 5 (continued)

Sampling Date	Site 1	Site 2	Site 3
7/22	0.0240	0.0415	0.0000
7/25	0.0000	0.0000	0.0000
7/29	0.0407	0.0926	0.0000
7/31	0.0000	0.0000	0.0328
8/05	0.0879	0.0534	0.3638
8/07	0.0570	0.0862	0.0000
8/14	0.0000	0.0000	0.0000
8/19	0.0407	0.0602	0.0000
8/21	0.0256	0.0000	0.0000
8/26	0.0422	0.0000	0.0000
8/29	0.0000	0.0000	0.0000
9/01	0.0296	0.0267	0.0000
9/03	0.0300	0.0383	0.3170
9/09	0.0000	0.0000	0.0000
9/12	0.0000	0.0000	0.0000
9/15	0.0000	0.0000	0.0000

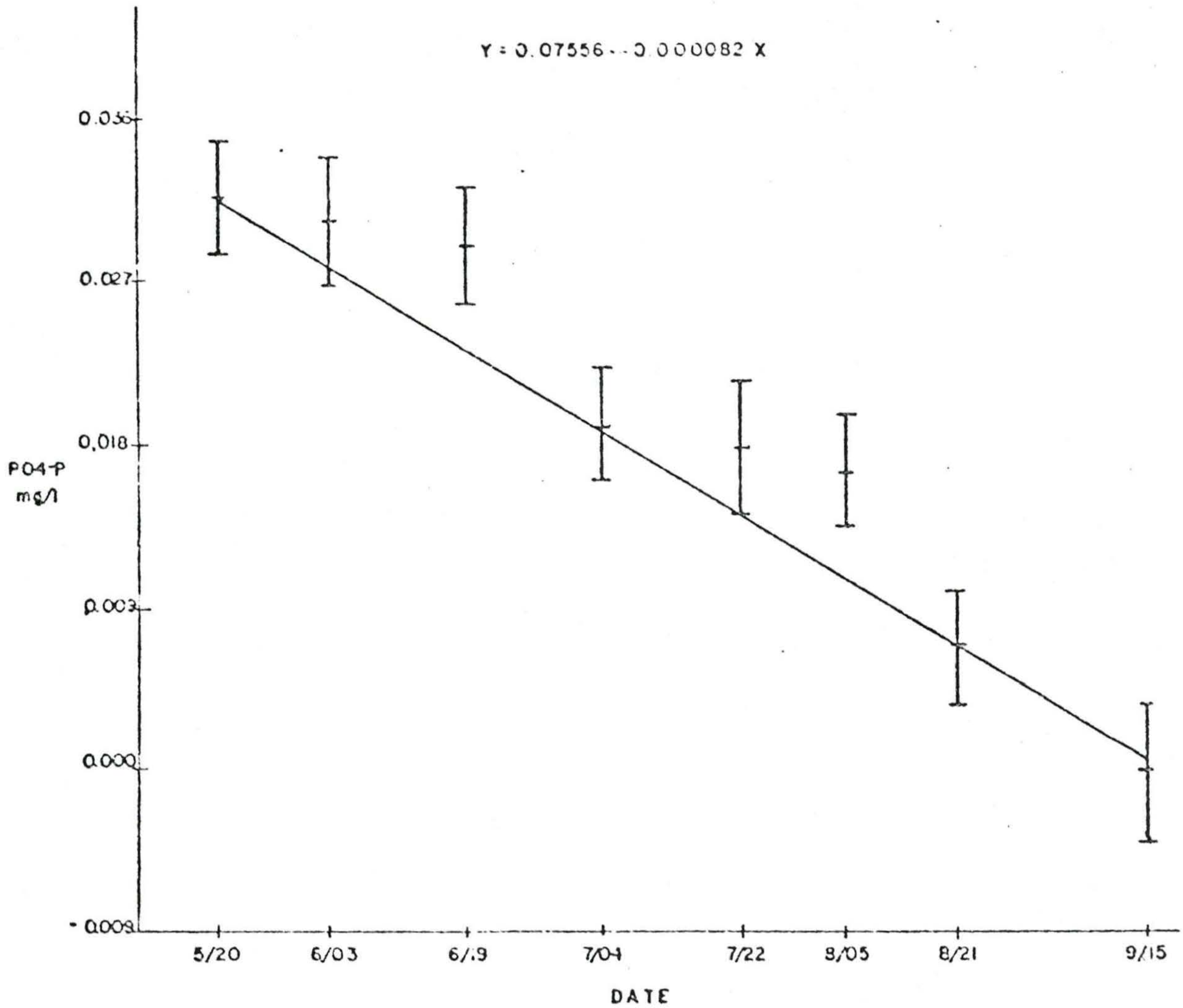

Figure 4

Regression (n=444) of Orthophosphate Sample Concentrations (PO_4-P mg/l) Plotted Against Elapsed Time Since May 13, 1979, with Mean (n=12) Sample Concentrations for Eight Selected Dates

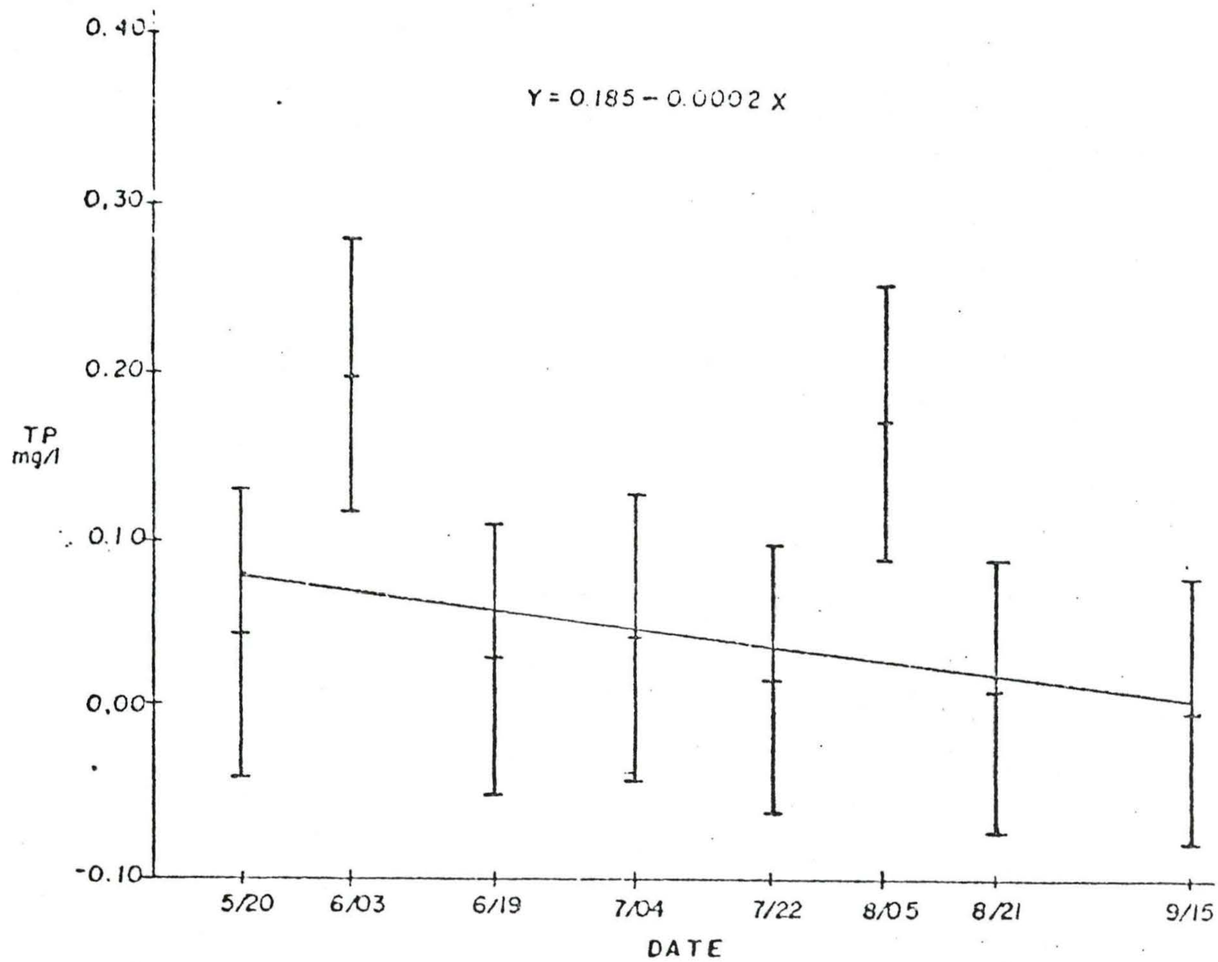

Figure 5

Regression (n=111) of Total Phosphorous Concentrations (TP mg/l) Plotted Against Elapsed Time Since May 13, 1979, with Mean (n=3) Sample Concentrations for Eight Selected Dates

Periphyton:

At each site, for each date, species identification procedures produced the following composite:

Top Most Abundant Species

In decreasing order of abundance the ten most common periphyton species were: 1) Cymbella affinis 35.54%, 2) Nitzschia fonticola 14.28%, 3) Achnanthes minutissima 11.92%, 4) Cocconeis placentula var. euglypta 8.48%, 5) Navicula cryptocephla var. veneta 7.27%, 6) Epithemia sorex 4.80%, 7) Nitzschia frustulum 3.58%, 8) Achnanthes lanceolata 2.09%, 9) Navicula miniscula 1.53%, and 10) Nitzschia kutzingiana 1.40%.

These species accounted for 91.4% of all species counted. The average densities, at all sites, for each sampling date were as follows (in cells/mm^2):

5/3	5/24	6/14	7/10	7/30	8/20	9/10
1648	4605	194	545	3892	5498	8468

Appendix 2 contains the density lists for each date, by locations with a notation for both standing crop and colonization measurements. A tabulation of the cell densities (cells/mm^2) is also included in Appendix 2: it has the statistical parameters of both mean and standard deviation noted thereon.

The similarity indices used to represent community structure were tabulated and are presented in Table 6.

Because of the importance of stream velocity and temperature to periphyton colonization and development, these values were monitored to be certain that they remained relatively uniform, as was planned (see Tables 7 and 8).

Table 6

Δ Similarity Values (SIMI) for Periphyton Communities for Site 1 (S_1), Site 2 (S_2), and Site 3 (S_3) at Slide Rock, Arizona, 1979.

(A Value of "1" Suggests the Two Communities are Identical)

Standing Crop

Date	S_1-S_2	S_1-S_3	S_2-S_3
5/3	.866	.964	.756
5/24	.887	.834	.782
6/14	.837	.901	.779
7/10	.388	.945	.370
7/30	-	-	-
8/20	.799	.676	.944
9/10	.951	.753	.866

Colonization, 21 day period

Date	S_1-S_2	S_1-S_3	S_2-S_3
5/24	.937	.751	.830
6/14	.879	.921	.890
7/10	.693	.911	.802
7/30	.957	.947	.992
8/20	.908	.915	.994
9/10	.937	.972	.980

Table 7

Slide Rock - Stream Velocity Data
1979
(Data expressed as average of at least 2 readings, usually 2-5 readings.)

Location	5/3	5/24	6/14	7/10	7/30	8/20	9/10	Mean
	cm/sec							
Site 1	35.5	40	9	23.3	22	15	17.3	23.2
Site 2	40	38.5	18.5	18.0	31.5	29	31	29.5
Site 3	-	-	57.2	55.3	43.5	29.5	30.7	43.2

Table 8

Slide Rock - Water Temperature Data
1979

Date	Ave. Water Temp. °C	Date	Ave. Water Temp. °C
13 May	13.5	15 July	17.0
20 May	11.8	22 July	17.8
27 May	16.0	29 July	19.0
3 June	15.5	5 Aug.	17.8
10 June	16.8	12 Aug.	15.0
17 June	14.5	19 Aug.	14.2
24 June	16.5	26 Aug.	14.3
1 July	15.0	2 Sept.	14.4
8 July	15.5	9 Sept.	14.5

Recreational Activity:

Through an informal cooperative arrangement with personnel of the Coconino National Forest, several tabulations of persons observed using the area were made during the May-September period. Table 9 reflects this data as well as the discharge measurement information collected at the same time.

The climate during August 1979 was characterized by generally below normal mean daily temperatures, especially during the latter part of the month. The use of Slide Rock may have decreased as a result of this phenomenon for it is apparent that starting around 10 August, afternoon recreational use was noticeably less than during the prior four-week period. The maximum use occurred on Labor Day. The spring-fed flow of Oak Creek remained relatively constant, and as might be expected, there appears to be no relationship between visitor use and total streamflow through the slides. It should be noted that there is no data to indicate the actual number of persons actually in the creek at any one time: the assumption is made that the more people in the designated area, the more the use of the creek (or the slides) for various full-body contact activities.

Bacteriological Indicators:

The Coconino National Forest hydrologist provided the information in Table 10. These data were also made available to the District Ranger of the Sedona District (Memo 2540, 16 January 1980) and were collected as part of an ongoing effort to monitor use of, and impacts to, this area.

Table 9
Recreationists and Stream Discharge for
Slide Rock, Selected Dates, 1979

Date	Time	Discharge (cfs)	Persons
12 May	1330	-	120
2 July	1350	-	315
4 July	1350	-	575
7 July	1410	18.9	590
10 July	1315	17.9	249
15 July	1425	20.0	693
19 July	1340	14.4	308
28 July	1410	13.4	601
1 Aug.	1410	13.4	527
4 Aug.	1405	14.4	753
9 Aug.	1330	-	350
12 Aug.	1420	18.2	175
13 Aug.	1440	13.4	191
17 Aug.	1350	11.8	230
21 Aug.	1115	9.6	116
25 Aug.	1250	7.6	390
29 Aug.	1355	11.0	130
2 Sept.	1400	10.2	802
3 Sept.	1345	11.0	499
6 Sept.	1335	11.9	94
14 Sept.	1335	11.9	11

Table 10

Bacteriological Water Quality
Indicator Values, Selected Dates, 1979

Date	Fecal Coliforms (#/100 ml)	Fecal Streptoccoci (#/100 ml)
12 May	0	9
2 July	104	120
4 July	62	400
7 July	(unavailable)	154
10 July	43	60
15 July	750	400
19 July	180	284
28 July	TNTC	600
1 Aug.	280	124
4 Aug.	TNTC	236
9 Aug.	TNTC	(unavailable)
12 Aug.	800	TNTC
13 Aug.	170	685
17 Aug.	20	160
21 Aug.	12	50
25 Aug.	38	100
29 Aug.	9	43
2 Sept.	40	184
3 Sept.	50	175
6 Sept.	6	50
14 Sept.	12	82

TNTC = "Too Numerous to Count" by membrane filter procedures.

DISCUSSION

Initially it was assumed that the nutrient concentrations at sampling site one would be significantly greater than those at sites two and three, simply because of the large number of people using Slide Rock. Moreover, as implied in the introduction, one objective was to see if algal indicators were useful as "integraters" of the impact high-density recreation use had on a stream.

The results do not bear out either assumption. Nitrate-nitrogen was the only parameter studied that showed a significant difference between sample sites. Even so, the result was exactly opposite of that which was expected: site one, which was below the area of intense recreational use, showed a decrease in the concentration over sites two and three. Interestingly, this agrees with the findings of Sommerfeld et al. (1979).

One possible explanation for this observation is that the extensive periphyton community which covers the rocks in the slide area may have rapidly assimulated the nitrogen made available by intermittent human activity.

Hynes (1970) noted that the concentration of nitrate in stream water is usually low because the ions are rapidly taken up by aquatic vegetation. Running water makes this possible because the current prevents the accumulation of a shell of depleted water around the organism and constantly presents fresh material to its surface to replace that which is used up by the organism.

Furthermore, when weekdays were statistically analyzed separately from weekends and holidays, weekdays were the only samples that showed

the significant difference in nitrate concentration. A possible explanation for this event could be that on weekdays, when visitor use was low, a smaller amount of nitrate was added to the stream than on weekends and holidays. Assuming this reasoning, the periphyton then absorbed nitrate in excess of the amount that was added through recreational activities. On the other hand, during weekends and holidays, when recreational pressures were higher, more nitrate was probably added to the stream. If this were the case, and even though the attached algae may have absorbed a similar amount of nitrate as on weekdays, the greater addition of nitrate may have merely compensated that which was depleted. Therefore, a significant difference was not found on weekends and holidays.

The other chemical parameters did not show a significant difference between sample sites. It was thought that the effect of weekends and holidays might have masked the effect of weekdays, so they were statistically analyzed separately. The results did not bear out this hypothesis. This contradicts the findings of Sommerfeld et al. (1979). They found that ammonia and orthophosphate concentrations also decreased downstream. However, their study encompassed a much longer stream segment; also, their study was not concerned with one particular, heavily used area like Slide Rock, but a more diffuse type of recreation.

One cannot infer that people in and along the stream were not adding nutrients to the stream. As Hynes (1970) points out, although considerable amounts of nutrients may enter the stream, relatively small amounts may actually occur in solution in the water, especially during seasons of active plant or perhaps bacterial growth. Equally important, McColl (1974) found that in a stream with nutrient poor waters, nutrients were

removed rapidly and efficiently, whereas in a stream which received nutrients continuously from a sewage outfall, nutrients were not significantly removed by the streambed flora. We postulate that it is the intermittent nature of recreational activity which renders it so inconsequential in this setting.

People only affect Slide Rock for perhaps eight hours a day and then only in waves, or pulses. There was not a constant addition of nutrient material, as one would expect below a sewage outfall, and it may be that the stream ecosystem is quite capable of absorbing - with essentially no change in composition in the flora - these pulses, if indeed there were such. In addition, it has been shown that many algae, when supplied with a sufficient supply of nutrients, can absorb them in quantities far in excess of their actual needs (Wetzel 1975). Therefore, it seems possible that the attached algae could have absorbed the nutrients as quickly as they were added, and stored them for use when they were in short supply.

Nitrate, ammonia, orthophosphate, total Kjeldahl nitrogen, and total phosphorous all showed a significant regression on date. In addition, regression analysis revealed that date had the highest correlation with each of the chemical parameters. In summary, the results indicated a seasonal trend of decreasing concentration for all. Generally seasonal differences in the discharge of Oak Creek are not pronounced after the snow melt season, although daily fluctuations may result from precipitation events. A possible explanation for the seasonal decrease in nutrient concentrations, however, may lie in the seasonal uptake of these ions by the riparian and algal vegetation.

Terrestrial vegetation, when dormant, has a low evapotranspirational potential. This would allow more water to percolate through the soil material and possibly leach nutrients while enroute to the stream system. As dormancy breaks, more water and nutrients would be withdrawn from the soil, decreasing the amount which would be added to the stream. Bormann and Likens (1979) found that nitrate concentrations in the stream water showed a pronounced seasonal pattern at Hubbard Brook. Nitrate was markedly reduced during the growing season. Furthermore, they noted that reduced streamflow, due to increased evapotranspirative demands, acts as a nutrient conservation mechanism because reduced streamflow means less nutrients are carried out of the terrestrial ecosystem.

Aquatic vegetation may also influence the seasonal response exhibited by the nutrients in this study. Channel scour during high flows decreases the periphyton on the rock surfaces at a time when the highest nutrient loads occur (Ball and Bar 1975). Hence, a larger proportion of the nutrient load would be carried through the lotic community at a time when the system is least capable of utilizing it. As flows decline and radiation increases, the attached algae begin to increase in numbers. Blinn (unpublished data) found that the periphyton cell numbers per mm^2 of rock substrate, at a site below Slide Rock, increased from 1170 cells on July 10, 1979 to 7270 cells on September 10, 1979. Such an increase in periphyton population, when extended to the total rock surface area in contact with the stream, could create a markedly increased capacity to absorb nutrients. Ball and Bar (1975) found that most additions of nitrogen and phosphorous to a stream are taken up by plant communities.

Although over an annual period, incoming nutrients from all sources are eventually transmitted downstream, the warmer summer temperatures and increased radiation encourage the biological incorporation of nutrients, thus temporally halting the flux of nutrients through the system. It appears that the periphyton population could be a factor which might explain the decreasing trend in the nutrient loadings of Oak Creek at Slide Rock.

If the previous arguments explain the seasonal trend exhibited by the chemical parameters which were monitored adequately in this study, then one would expect an increasing trend at the end of the growing season. However, this study was limited to the months of May through September and probably did not include the time period in which an increase occurred. The algae data (Appendix 2) seem to support this assumption as the cell counts increased through the end of the sampling period. Perhaps if the sampling period had been extended to the end of the year, the trend might have reversed.

Sampling coincided with precipitation events on four dates. It was conjectured that precipitation would wash into the stream material which had possibly built up on rock surfaces along the stream as a result of recreational activities between storms. However, no significant differences were found when concentrations on these dates were compared against concentrations on days when no precipitation occurred. These results contradict those of Morrison and Fair (1966). They found, in continuous sampling of two storm events, that ammonia nitrogen and orthophosphate concentrations increased on the rising limb of the hydrograph and decreased after the crest. Since only one sample was taken for

each precipitation event, the period of increasing concentrations may not have been sampled. Or, perhaps, the precipitation events may not have been of sufficient intensity or duration for overland flow to have occurred.

No significant difference was found among the four sample points at each sample site for any of the chemical parameters. Evidently the waters of Oak Creek at Slide Rock were well mixed and only one sample at each site was needed.

CONCLUSIONS

The number of people using Slide Rock appeared to have no effect on the chemical (nutrient) concentrations of the water; moreover, weekend concentrations were not significantly different than weekday concentrations. This was not true with fecal coliforms and streptococci, however. While fecal coliform counts varied widely, it appears that low levels of activity ($\leq$250 persons per day) are not associated with fecal coliform counts greater than 200 colonies/100 ml.

The periphyton community demonstrated no significant shift in structure over the sampling period. There was a small increase in density. These data suggest that stream ecosystems are very resilient to heavy recreational use (as many as 600 people/100 feet by 500 feet section) and that the biotic micro-components can assimilate these intermittent inputs very rapidly with no significant modification in community structure.

Date appears to be the most significant factor in explaining chemical changes noted in the system: nutrient concentrations decreased

throughout the summer months of 1979.

APPLICATIONS

At Slide Rock the periphyton community did not react to the impact of people on water quality, if indeed it was affected by such activity. Moreover, except for rather small fluctuations in fecal coliform and fecal streptococci counts, water quality appeared unchanged.

From this limited data, it does not appear that current levels of recreational use will have any long term consequences on the Oak Creek ecosystems. A mechanism which may explain the resilience of the system to this obvious impact might be the intermittent nature of the loading: such a premise deserves further investigation.

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APPENDIX 2

STATISTICAL SUMMARY TABLES

A.1	Statistical Data
A.1.1	Multiple Regression Summary Tables
A.1.1.1	Dependent Variable - Nitrate
.2	Dependent Variable - Ammonia
.3	Dependent Variable - TKN
.4	Dependent Variable - Orthophosphate
.5	Dependent Variable - Total Phosphate
A.1.2	Supporting Data Summary Tables
A.1.2.1	Numbers of People at Slide Rock and Above Slide Rock, Selected Dates, 1979
.2	Water Temperature, Air Temperature, Number of Dogs Observed, Stage

A.1.1.1
Multiple Regression Summary Table with Nitrate
as the Dependent Variable

Dependent Variable	Independent Variable Stepwise Inclusion	R^2	Mean Square Residual	F Value	Variables with Non-Significant Partial F Values
NO_3	Date	0.39430	0.00041	287.7353	
NO_3	Stage	0.45353	0.0037	182.9966	
NO_3	Water Temperature	0.47972	0.0036	135.2323	
NO_3	Dogs	0.49497	0.00035	107.5643	
NO_3	Weekends and Holidays	0.50831	0.00034	90.5605	
NO_3	Sample Site	0.51483	0.00034	77.2851	
NO_3	Time of Sampling	0.51826	0.00032	67.0885	Time
NO_3	Raining or Not	0.52005	0.00032	58.9169	Time, Rain
NO_3	Sample Point	0.52057	0.00032	52.3599	Time, Rain, Point
NO_3	Number of People	0.52101	0.00033	47.0979	Time, Rain, Point, Number of People

F level Insufficient for Further Computation

A.1.1.2
Multiple Regression Summary Table with Ammonia as the Dependent Variable

Dependent Variable	Independent Variable Stepwise Inclusion	R^2	Mean Square Residual	F Value	Variables with Non-Significant F Values
NH_3	Stage	0.07484	0.00017	35.7562	
NH_3	Sample Site	0.07897	0.00017	18.9061	Site
NH_3	Number of People	0.08328	0.00017	13.9061	Site, People
NH_3	Number of Dogs	0.08615	0.00017	10.3465	Site, People, Dogs
NH_3	Water Temperature	0.08807	0.00017	8.4605	All but Stage
NH_3	Weekends or Weekdays	0.08900	0.00017	7.1150	All but Stage
NH_3	Time of Sampling	0.08996	0.00017	6.1572	All but Stage
NH_3	Raining or Not	0.09070	0.00017	5.4237	All but Stage
NH_3	Date	0.09104	0.00017	4.8269	All but Stage
NH_3	Air Temperature	0.09106	0.00017	4.3381	All but Stage

F Level Insufficient for Further Computation

A.1.1.3
Multiple Regression Summary Table with TKN as the Dependent Variable

Dependent Variable	Independent Variable Stepwise Inclusion	R^2	Mean Square Residual	F Value	Variables With Non-Significant F Values
TKN	Date	0.44381	0.02590	86.9766	
TKN	Raining or Not	0.45366	0.02568	44.8401	Rain
TKN	Water Temperature	0.46882	0.02523	31.4033	Water Temperature
TKN	Sample Site	0.47957	0.02492	24.4190	Site
TKN	Stage	0.49824	0.02454	20.3639	Stage, Site
TKN	Time of Sampling	0.49824	0.02449	17.2114	Time, Stage, Site
TKN	Number of Dogs	0.50434	0.02442	14.9718	Dogs, Time, Stage
TKN	Air Temperature	0.50530	0.02462	13.0235	Air Temperature, Dogs, Time, Stage, Site
TKN	Weekends or Weekdays	0.50551	0.02485	11.4724	Weekends, Air Temperature, Dogs, Time, Stage, Site
TKN	Number of People	0.50556	0.02509	10.2292	All But Date and Rain

A.1.1.4
Multiple Regression Summary Table with Orthophosphate
as the Dependent Variable

Dependent Variable	Independent Variable Stepwise Inclusion	R^2	Mean Square Residual	F Value	Variables with Non-Significant Partial F Values
PO_4	Date	0.65472	0.000054	838.1301	
PO_4	Weekends or Weekdays	0.66429	0.000053	436.31	
PO_4	Number of Dogs	0.67065	0.000052	298.66	
PO_4	Water Temperature	0.67303	0.000051	225.91	Water Temperature
PO_4	Number of People	0.67820	0.000051	184.62	Dogs
PO_4	Stage	0.68195	0.000051	156.1662	Dogs
PO_4	Sample Site	0.68332	0.000051	134.39	Dogs, Site
PO_4	Time of Sampling	0.68392	0.000051	117.66	Dogs, Site, Time
PO_4	Raining or Not	0.68441	0.000051	104.51	Rain, Site, Site, Dogs
PO_4	Sample Point	0.68481	0.000051	94.07	Point, Rain, Time, Site, Dogs
PO_4	Air Temperature	0.68500	0.000051	85.4014	Air Temperature, Point, Rain, Time, Site, Dogs

A.1.1.5
Multiple Regression Summary Table with Total Phosphorous as the Dependent Variable

Dependent Variable	Independent Variable Stepwise Inclusion	R^2	Mean Square Residual	F Value	Variables With Non-Significant Partial F Values
TP	Date	0.08730	0.00687	10.4261	
TP	Time	0.12307	0.00666	7.5786	
TP	Raining or Not	0.14207	0.00658	5.9061	Rain
TP	Stage	0.15527	0.00654	4.87	Time, Rain, Stage
TP	Sample Site	0.16352	0.00653	4.1052	All But Date
TP	Weekends or Weekdays	0.16784	0.00650	3.4960	All But Date
TP	Water Temperature	0.17202	0.00659	3.0520	All But Date and Rain
TP	Number of Dogs	0.17556	0.00633	2.7150	All But Date
TP	Number of People	0.17980	0.00664	2.4601	All But Date
TP	Air Temperature	0.18007	0.00673	2.1962	All But Date

A.1.2.1

The Number of People at Slide Rock and Above on Sampling Dates in 1979. Asterisks Denote Weekends and Holidays

Sampling Date	Slide Rock	Above Slide Rock	Sampling Date	Slide Rock	Above Slide Rock
*5/13	196	12	*7/14	593	38
5/15	54	0	7/17	161	4
*5/20	5	0	*7/22	608	41
5/22	21	0	7/25	289	10
*5/26	5	0	*7/29	644	38
5/29	451	37	7/31	338	0
*6/03	119	5	*8/05	628	34
6/05	112	11	8/07	607	41
*6/10	367	24	8/14	157	2
6/12	197	4	*8/19	370	21
*6/17	376	18	8/21	258	8
6/19	156	0	*8/26	578	29
*6/24	506	38	8/29	99	0
6/26	210	6	*9/01	425	12
*6/30	491	17	*9/03	496	20
*7/02	385	12	*9/09	243	10
*7/04	682	33	9/12	21	2
*7/07	544	57	*9/15	289	10
7/10	119	0			

Mean (n=21) Weekend and Holiday 430 (216) SD

Mean (n-16) Weekday 210 (169) SD

Mean (n=37) Total 335 (223) SD

A.1.2.2

Summary Table of Supporting Data. Asterisks Denote Samples Collected on Days when Rainfall Occurred

Date	Air Temperature Degrees Celcius	Water Temperature Site			Number of Dogs	Stage **
		1	2	3		
5/13	29	15	15	15	2	
5/15	28	16	16	16	1	
*5/20	2	12	11	11	0	
5/22	23	14	13.5	13.5	0	
*5/26	12	11	11	11	0	
5/29	32	16	15	15	0	-33
6/03	26	15	15	15	0	-56
6/05	28	16	16	16	1	-75
6/10	30	16	15	15	4	-55
6/12	33	18.5	17	17	0	-58
6/17	30	15	15	15	2	-56
6/19	30	15.5	14	14	0	-55
6/24	34	17.5	16.5	16.5	0	-57
6/26	36	18	18	18	0	-61
6/30	34	20.5	19.5	19.5	0	-62
7/02	34	20.5	19.5	19.5	0	-66
7/04	34	16.5	16	16	0	-70
7/07	30	17	16	16	0	-68
7/10	31	16	14.5	14	0	-71
7/14	35	19	18	18	0	-75

A.1.2.2 continued

Date	Air Temperature Degrees Celcius	Water Temperature Site			Number of Dogs	Stage **
		1	2	3		
7/17	31	17	17	17	0	-87
7/22	34	19	17.5	17.5	4	-88
7/25	36	19.5	18	18	0	-110
7/29	35	20	19	18.5	0	-80
7/31	35	20	19	18.5	0	-65
8/05	33	19	18	18	0	-68
8/07	33	19	17.5	17.5	0	-73
*8/14	28	16	16	15	0	-77
*8/19	22	15	15	14	0	-80
8/21	29	16	14.5	14.5	0	-82
8/26	31	17	16	15.5	2	-83
8/29	31	15	14.5	14	2	-81
9/01	32	15.5	14.5	14.5	0	-79
9/03	32	17	16	15.5	0	-85
9/09	32	17	16	16	0	-79
9/12	32	15	14	14	0	-74
9/15	25	14	13.5	13	0	-73

**With reference to Garland's Crossing datum of 24 May]979.

APPENDIX 2

PERIPHYTON DATA

A.2.1 Species Code List (for tables below)

A.2.2 Relative Density by Species-5/3/79

A.2.3 Relative Density by Species-5/24/79

A.2.4 Relative Density by Species-6/14/79

A.2.5 Relative Density by Species-7/10/79

A.2.6 Relative Density by Species-7/30/79

A.2.7 Relative Density by Species-8/20/79

A.2.8 Cell Densities (cells/cm^2) at All Sites, for All Dates

A.2.1-SPECIES CODE LIST FOR DIATOMS AT SLIDE ROCK, ARIZONA

1. Achnanthes lanceolata
2. A. lanceolata var. dubia
3. A. lanceolata var. omissa
4. A. minutissima
5. A. saxonica
6. Amphora perpusilla
7. Asterionella formosa
8. Cocconeis placentula var. euglypta
9. C. pediculus
10. Cyclotella meneghiniana
11. Cymbella affinis
12. C. Cymbiformis var. nonpunctate
13. C. mexicana
14. C. minuata
15. C. sinuata
16. Diatoma vulgare var. linearis
17. Epithemia sorex
18. E. turgida
19. Fragilaria construens var. venter
20. F. leptostauron
21. Gomphoneis herculeana
22. Gomphonema parvulum
23. G. subclavatum
24. G. truncatum
25. G. ventricosum
26. Hantzschia amphioxys
27. Melosira varians
28. Meridion circulare
29. Navicula bacillaris
30. N. cryptocephla
31. N. cryptocephla var. minuta
32. N. cryptocephla var. veneta
33. N. decussis
34. N. miniscula
35. N. tripunctata var. schizomoides
36. Nitzschia acicularis
37. N. dissipata
38. N. fonticola
39. N. frustulum
40. N. kutzingiano
41. Rhoicosphenia curvata
42. Rhopalodia gibberula var. vanheurckii
43. Surriella angustata
44. S. ovata
45. Synedra acus
46. S. incisa
47. S. rumpens var. familiaris
48. S. ulna

A.2.2-RELATIVE DENSITIES-5/3/79
(Standing Crop Only)

Species Code #	1S	2S	3S
1	0	0.1	0.1
2	0	0	0
3	0	0	0
4	18.5	28.9	15.2
5	0	0	0
6	0	0	0
7	0.1	0	0
8	0	0	0.1
9	0	0.2	0
10	0	0	0
11	4.3	2.1	5.3
12	0	0	0
13	0	0	0
14	0	0	0
15	4.6	3.1	11.7
16	0	0.1	0
17	0	0	0
18	0	0	0
19	0	0	0
20	0	0	0.1
21	0	0	0
22	0	0	0
23	0	0	0
24	0	0	0
25	0	0.3	0.1
26	0	0	0
27	0	0	0
28	0	0	0
29	0	0	0
30	0	0.6	0
31	0	0	0
32	42.7	21.2	40.0
33	0.1	0.3	0
34	0	0	5.2
35	0	0	0
36	0	0	0
37	0	0.1	2.7
38	26.9	41.7	15.8
39	0	0	0
40	2.4	0.5	3.1
41	0	0.1	0
42	0	0	0
43	0	0	0
44	0	0	0
45	0	0	0
46	0	0	0
47	0.3	1.0	0.7
48	0	0	0
Total # Species Present	9	15	13

A.2.3-RELATIVE DENSITIES-5/24/79
(Standing Crop and Colonization)

Species Code #	1S	1C	2S	2C	3S	3C
	Locations					
1	0.7	11.2	0.4	6.6	0.2	2.0
2	0.4	0.6	0	0.5	0	0.9
3	0	0.5	0.6	0.1	0	0
4	22.3	30.3	25.3	23.6	9.6	16.5
5	0	0	0.1	0	0	0
6	0	0.8	0	0.4	0	1.1
7	0	0	0	0	0	0
8	6.1	10.1	1.3	5.8	0.3	7.4
9	1.4	1.3	0.3	2.4	0	0.4
10	0	0.1	0	0.4	0	0
11	1.0	1.4	21.3	10.3	4.6	2.8
12	0	0	0	0	0	0
13	0	0.1	0	0	0	0
14	0	0.4	0	0.6	0	0
15	5.4	2.4	1.1	1.3	0	0.8
16	0	0	10.3	1.2	0	2.4
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0.3	0	0.7	0	0.4
20	0	0	0	0	0	0
21	0	0.2	0	1.7	0	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0.9	0	0	0	0	0
25	0	0	0	0.3	0	0.6
26	0	0	0	0	0	0
27	0	0	0	0	0	1.1
28	0	0.7	0	0	0	0
29	0	0	0	0	0	0
30	0	0.07	0	0.6	0	1.1
31	0	0	0	0	0	0
32	11.8	19	5.6	20.0	6.6	16.2
33	0	1.4	0	0	0	0.6
34	0	0.3	3.5	0.3	3.5	5.4
35	0	0.9	0.1	0.4	0	0.2
36	0	0	0	0	0	0
37	0.3	4.1	0.7	4.2	15.3	1.3
38	49.2	11.6	37.0	15	40.2	34.9
39	0	0	0	0	0	0
40	0.3	0.7	1.8	1.7	19.7	3
41	0	0.3	0	0.3	0	0.2
42	0	0.1	0	0.7	0	0
43	0	0	0	0.4	0	0
44	0	0.07	0	0	0	0
45	0	0	0	0	0	0
46	0	0.1	0.1	0.1	0	0
47	0.3	0.5	0	0.5	0	0.4
48	0	0.8	0	0.9	0	0.4
Total # Species Present	13	29	17	28	9	23

A.2.4-RELATIVE DENSITIES-6/14/79
(Standing Crop and Colonization)

Locations

Species Code #	1S	1C	2S	2C	3S	3C
1	2.4	11.1	1.6	8.7	2.2	2.4
2	0	0	0	0.3	0	0
3	0	0	0	0	0	0
4	12.2	21	28.7	28.8	16.2	16.9
5	0	0	0	0	0	0
6	0	0.9	0	0	0	0
7	0	0	0	0	0	0
8	27.3	32.7	3.2	18.2	19.8	30.7
9	1.2	0.3	0	0.3	1.5	1.2
10	0.4	0	0	0	0	0
11	0.4	0.5	0.4	2.8	1.5	9
12	0	0	0	0	0	0
13	0	0	0	0	0	0
14	0	0	0	0	0	0
15	1.6	1.4	2.8	2.8	0.7	1.8
16	0	0	0	0	0	0
17	0	0	0	0	0	0
18	0	0	0	0	0	0
19	0	0	0.1	0	0	0
20	0	0.2	0	0	0	0
21	0	0.1	0	0	0.7	0
22	0	0	0	0	0	0
23	0	0	0	0	0	0
24	0	0	0	0.3	0	0
25	0	0.3	0	0.3	1.5	0.6
26	0	0	0	0	0	0
27	0	0	0	0	0	0
28	0.4	0.6	0	0	0	0
29	0	0	0	0	0	0
30	0	0	0.2	0	1.5	0
31	0	0	0	0.3	0	0
32	5.7	9.8	6.1	11.5	11	13.2
33	0	0.1	0.2	0.6	0	0
34	2.1	5.1	0.7	2.8	15.4	0.6
35	0.4	1.4	0	0.3	0	1.2
36	0	0	0	0	0	0
37	2.9	1.6	0.1	0.3	1.5	1.2
38	37.6	8.3	55.1	20.2	25	17.5
39	0	0	0	0	0	0
40	3.7	2.9	0.1	1.7	1.5	2.4
41	0	0.3	0	0	0	0
42	0	0	0	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0.8	1.1	0.1	0.6	1.5	1.2
48	0	0	0	0	0	0
Total # Species Present	15	20	14	18	15	14

A.2.5-RELATIVE DENSITIES-7/10/79
(Standing Crop and Colonization)

Locations

Species Code #	1S	1C	2S	2C	3S	3C(old)	3S
1	5.8	4.8	0.6	1.6	10	2.6	0.1
2	0	1	0	0	0	0	0
3	0	0	0	0	1.5	0	0
4	22	14.7	4.8	18.9	25.4	13.7	4.4
5	0	0	0	2.9	0	0	0
6	0	0.8	0	0.2	0.2	3.4	0
7	0	0	0	0	0	0	0
8	32.4	29.6	9.2	12	22.2	20.5	2.1
9	0.4	0.8	0.6	1.0	0	0.8	0
10	0.9	1.8	0.1	1.1	1.0	0.8	0
11	9.3	6.4	61.9	31.1	6.8	12	61.7
12	0	0.1	0	0.2	0	0	0.1
13	0	0	0	0	0	0	0
14	0	0	0	0	0	0	0
15	0.2	0.9	0.8	1.2	0.1	4.3	0.7
16	0.4	0.2	0	0.7	0	0	0.1
17	0	0.4	0.1	0.2	0.4	0	0.1
18	0	0.1	0	0	0	0	0
19	0	1.2	0	0	0	0.8	0
20	0	0	0	0.1	0.7	0	0
21	0	1.1	0	0.06	0.4	0	0
22	0	0	0	0.4	0	0.8	0
23	0	0	0	0.3	0	0	0
24	0	0	0	0	0	0	0
25	1.2	0	0	0	0.1	0	0
26	0	0	0	0.06	0	0	0
27	0	0.6	0	0	0	0	0
28	0.4	0	0	0	0	0	0
29	0	0	0	0	0	0	0
30	0.9	1.2	0.1	1.5	0.1	0	0
31	0	0	0	0	0	0	0.1
32	10.2	6.6	2.5	4.4	11.5	6	0.6
33	0.9	0	0.1	0.2	1.1	0	0
34	0.2	0.7	0	1.2	3	2.6	1.5
35	0.4	1.2	0.6	0.2	0.1	0	0
36	0	0.1	0	0.2	0	0	0
37	0.2	1.8	0.1	0.5	0.1	1.7	0.9
38	3.7	14.8	17.1	13.5	9.3	24.8	27.4
39	4.6	3.3	0	3.5	3.2	2.6	0
40	0.5	2.7	0.1	1.5	1.4	0.8	0.1
41	0	0.1	0	0	0	0	0
42	0	0	0	0	0	0	0
43	0	0	0	0	0	0	0
44	0	0	0	0	0	0	0
45	0	0	0	0	0	0	0
46	0	0	0	0	0	0	0
47	1.6	.8	0.8	0.2	0	1.7	0
48	0.9	2.1	0.1	0.3	0.4	0	0
Total #Species Present	21	28	17	30	22	17	14

A.2.6-RELATIVE DENSITIES-7/30/79
(Standing Crop and Colonization)

Species Code #	Locations 1S	1C	2S	2C	3S	3C
1	1.0	2.0	0.06	0.8	0.1	0.9
2	0	0	0	0	0	0
3	0	0.9	0	0.2	0	0
4	7.1	11.2	4.4	2.6	4.1	5.6
5	0	0.2	0	0	0	0
6	0.2	1.6	0	0.3	0	1.5
7	0	0	0	0	0	0
8	7	9.8	1.5	5.2	1.2	2.4
9	0.5	0.8	0.1	0.2	0	0.2
10	0.4	0.2	0	0.1	0	0.2
11	60.1	42.6	77.1	70.1	77.8	74.8
12	0.7	0	0.5	0	0.8	0
13	0.05	0	0	0	0.1	0
14	0	0	0	0	0	0
15	1.2	0.2	1.0	0.3	0.3	0.6
16	0.5	0.1	0.1	0	0	0.2
17	3.3	2.7	0.5	1.9	1.1	0.2
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	0.4	0.2	0.1	0.4	0.05	0
22	0.2	0.4	0	1.2	0.1	0.2
23	0	0	0	0	0	0
24	0	0.5	0	0	0	0
25	0	1.2	0	1.5	0	.2
26	0	0	0.06	0	0	0
27	0	0.4	0	0.2	0	0
28	0	0	0	0	0	0
29	0	0.2	0	0	0	0.2
30	1.2	1.9	0.2	1.4	0.4	0.6
31	0	0.2	0	0	0.1	0.2
32	2.1	4.8	1.5	2.4	0.9	1.4
33	0.2	0.2	0	0.2	0	0.3
34	2.2	1.2	1.0	0	1.7	0.1
35	0.05	0	0	0	0.3	0
36	0	0	0	0	0	0
37	0.7	1.4	0.06	0.7	0.3	0.6
38	6.0	9.3	10.6	8.0	10.4	3.1
39	2.7	3.2	0.6	0.9	0.6	6.1
40	1.4	0.4	0.5	0	0.4	0.4
41	0.2	0	0	0.3	0	0
42	0	0	0	0	0	0
43	0	0.1	0.06	0.1	0	0
44	0	0	0	0	0	0
45	0	0.9	0	0.2	0	0
46	0	0	0	0	0	0
47	0.2	0	0	0.1	0	0
48	0.1	0.2	0	0	0	0
Total # Species Present	26	30	19	24	19	22

A.2.6-RELATIVE DENSITIES-8/20/79
(Standing Crop and Colonization)

Locations

Species Code #	1S	1C	2S	2C	3S	3C
1	0.2	1.4	0.3	0.1	0.3	0.1
2	0	0.5	0	0	0	0.1
3	0	0.1	0	0	0	0
4	2.6	4.5	4.6	1.6	0.6	8.3
5	0	0	0	0	0	0
6	0.5	0.3	0.2	0	0.3	0.4
7	0	0	0	0	0	0
8	2.9	5.8	3.3	2.6	0.8	2.9
9	0	0.1	0.2	0.1	0	0
10	0.1	0.2	0.3	0.2	0.1	2
11	37.3	38.2	67.4	75.8	84.2	66.7
12	0.4	0.4	0.3	0.5	1.5	0.7
13	0	0	0	0	0	0
14	0	0.1	0	0.2	0	0
15	0	0.7	0.2	0.3	0.2	0.2
16	0	0.1	0	0	0	0
17	42.7	15.2	14.4	3.7	2.9	3.8
18	0	0	0	0	0	0
19	0	0	0	0	0	0
20	0	0	0	0	0	0
21	1.5	2.2	0	0.2	0	0.1
22	0.8	0.3	0	0.2	0	0.8
23	0	0	0	0	0	0
24	0	0.1	0	0	0	0
25	0.8	0	0	0	0.1	0
26	0	0	1.1	0	0.2	0
27	0.6	1.2	0	1.0	0.1	0.2
28	0	0	0.3	0	0	0
29	0	0	0	0	0	0
30	1.5	4	0	2.3	0	3.3
31	0.3	0	1.4	0	0.3	0
32	0	2.3	0.2	1.3	0.1	0.9
33	0	0.2	0.2	0.2	0	0
34	0.2	1.0	0.2	0.3	0.2	0.9
35	0.1	0.2	0	0.4	0.3	0.2
36	0	0	0.4	0.2	0	0.2
37	0.5	2.5	0	0.6	0.3	1.0
38	0.3	5.7	0.2	1.7	2.2	3.0
39	6.7	12.2	1.9	5.5	4.3	3.9
40	0	0.8	1.9	0.4	0	0.4
41	0.1	0.3	0	0	0	0.1
42	0	0	0.2	0	0	0
43	0	0	0	0	0	0
44	0	0	0	0	0	0
45	0	0	0	0	0	0
46	0	0	0	0	0	0
47	0	0	0	0.2	0	0.1
48	0	0.3	0	0.3	0	0.3
Total # Species	29	30	31	32	19	25

A.2.8-CELL DENSITIES (cells/mm^2) AT ALL SITES FOR ALL DATES WITH MEAN VALUES (Y) AND STANDARD DEVIATIONS (S) FOR EACH DATE

	5/13		5/24		6/14		7/10		7/30		8/20		9/10	
	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S	$\bar{X}$	S
Site 1S	1787	1053	242	120	82	20	619	866	2633	1590	10,495	3,748	15,877	7649
Site 1C	-	-	1985	1163	660	714	1647	1213	7404	687	9,782	3,109	6,200	1736
Site 2S	1243	1062	7602	4112	457	120	215	79	4662	2083	1,378	586	2,259	542
Site 2C	-	-	2022	441	177	16	542	453	5187	2404	3,231	493	5,675	244
New Site 3S	1914	2204	5973	6000	45	10	1170	886	4381	2017	4,621	3,270	7,270	3851
New Site 3C	-	-	179	184	55	43	-	-	3202	1689	1,099	540	3,419	157